National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Mapping Worlds That Look Like Stars

Objective

To demonstrate methods developed by astronomers to map objects too distant to show detail when viewed with a telescope.

Time Required: 1 hour

Saturn System Analogy: The small, distant moons in the Saturn system

Keywords: Asteroid, Color, Mapping, Photometry, Reflected Light, Rotation

Asteroid Gaspra, as seen by the Galileo spacecraft.

MATERIALS

- Peanuts in their shells: 3 or 4 for classroom demonstration (or per group of students), with different sizes and shapes (small colored clay forms may also be used as alternatives) that will become “asteroids”
- Black paper, cardboard, or cloth for sky background
- Colored marking pens
- Construction paper with colors matching the artificial asteroids and/or the colors of the marking pens
- Pencils with good, flexible erasers (one per peanut-asteroid) or lightweight monofilament fishing line
- Paper clips (one per peanut-asteroid)
- Optional: large (approximately 12"×12"×18") box, one per group of students

Discussion

Most individual objects in the universe are too distant for us to discern details on their outer layers, whether they are solid planets or gaseous planets or stars. With a handful of exceptions, the surface geographies of asteroids remain a mystery. Yet, astronomers have developed many techniques that yield a wide variety of information about these objects. In particular, measurements of the light intensity and color from objects can reveal parameters like rotation rate, shape, and geographic features.

To make these measurements, astronomers measure the sunlight reflected by an asteroid over the course of hours to days. In “integrated” (white) light, the strongest signal can be measured. Over the course of time, changes will be due to the rotation of the asteroid. If the asteroid is spherical, changes in the light reflected by the surface indicate differences in the reflectivity of surface materials. If the asteroid has a more complex shape, changes in reflected light can indicate both differences in surface materials and the effects of the different illuminated cross-section presented to observers on Earth.

Astronomers usually use filters to measure brightness in a variety of colors to better discriminate between geographic features and a changing cross-section. The variation in color even provides hints to the composition of the surface. All such astronomical measurements rely on comparison with constant-brightness background stars.

Procedure

Prepare your peanut-asteroids in advance, by mounting each one in a pencil-handle: bend a paper clip around the waist of the peanut or create a cradle or clasp for the peanut, sticking one end of the paper clip into the pencil's eraser so the peanut is separated from the eraser. The pencil will be much less distracting if it is dark-colored. Alternatively, monofilament strings can be tied around the peanuts so they can be suspended. Controlling their rotation will be more difficult, however, if string is used. Set up some peanut-asteroids so that they present different cross-sections to an observer as they rotate and at least one that does not change its apparent shape as it rotates.

The background sky and comparison stars should also be prepared in advance. Use black construction paper or black cloth (black velvet is especially effective) to make the background sky, large enough (about 1 meter square) for the classroom demonstration.

Cut out at least four circles of various sizes, one whose diameter is smaller than the smallest peanut and one whose diameter is larger than the longest peanut, from the construction paper that comes closest to matching the peanuts' color. Attach (with tape or glue) these "stars" to the black background. It is convenient to also have unique numbers or letters attached near the stars so students can discuss their comparisons of the asteroid with the stars.

Set up the classroom so that the overhead projector will shine its "sun" light on the sky background that has been mounted to the wall.

Stand near the background, being careful not to obscure any stars with your body as seen by students around the room. Holding a sample peanut-asteroid, ask the students to make a judgment about how bright the asteroid appears in comparison with the stars. Realize that students looking from different angles around the room will record different brightnesses. Rotate the asteroid 90 degrees and ask them to note the brightness, repeating this three more times (to confirm that the results "close" on themselves, i.e., that they return to the starting value). Repeat these observations with other peanut-asteroids.

Compare results around the room. The students will see that as tiny as the peanut appears from their seats, they can still tell that it is rotating and they can even get a feel for its relative dimensions. They may also note that because of the different viewing angle at the far ends of the room, there is a phase shift in when maximum/minimum apparent brightness occurs.

Variation and Extension

More "stars" for comparison allow more precise estimates of brightness and that can generate smoother light curves (a plot of brightness vs. time [in this case, asteroid orientation with respect to the viewer]). The light curve will also be smoother if brightness measurements are made at intervals spaced more closely than 90 degrees of rotation. Actual brightness measurements may be possible with a photographic spot meter.

Obtain two small balls (or marbles). One should be uniform in color, and the other should be painted black on one hemisphere. Mount them in the same manner as the peanuts and have the students observe their light curves. The uniform sphere will have no variations. The two-faced sphere will demonstrate that reflectivity (albedo) variations can mimic the effects of complex shapes.

Small groups of students can make their own observations by constructing a sky box. The box should have a viewing hole in one end and a starry sky background affixed to the inside of the other end. A hole in the side or top, near the sky background, should be large enough to allow insertion of a peanut-asteroid and allow it to be rotated.

Room light through the open box top provides illumination. It should be uniform on the comparison stars and the asteroid. Problems with illumination will illustrate experimental error.

Color some significant portions of the peanuts with the colored pens. Three possibilities can be pursued for the star background: (1) Create sets of similarly colored stars (from construction paper or white paper colored with the same pens). Your background, comparison star constellations will, of necessity, have many more stars since size-sets are needed in each color. (2) Use colored filters on the sun-analog (overhead projector). (3) For a sky box, filters can be interchanged at the eye-hole, in a manner similar to the way real astronomical observations are made. Colored gift wrapping film is an easily available and inexpensive source of color filter material. Have the students perform the same observations of the asteroids, but now they have to interpret the variations they see as being due to both shape and color reflectivity. Asteroids can also be constructed from clays of different colors and tested the same way.

Several vendors offer light measuring photometry systems that acquire data and plot it under computer control. Such systems can be adapted for quantitative measurements of the "asteroids" in this activity. Computerized data acquisition is common in many laboratories and is used almost exclusively in observatories.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

3. Understands the composition and structure of the universe and Earth's place in it.

LEVEL 3 (GRADES 6–8)

Knows characteristics and movement patterns of the nine planets in our solar system (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them.

10. Understands forces and motion.

LEVEL 1 (GRADES K–2)

Knows that the position of an object can be described by locating it relative to another object or the background.

LEVEL 2 (GRADES 3–5)

Knows that an object's motion can be described by tracing and measuring its position over time.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Mapping Worlds That Look Like Stars

Procedure

For each peanut-asteroid, write down the number of the "star" that has the closest brightness to the asteroid each time you are asked to make an estimate. You will do this five times for each asteroid.

Do the first and last estimates match each other? Why or why not?

What does the variation in brightness tell you about the asteroid?

Make a similar set of estimates for the colored "asteroids." Do the first and last estimates match each other? Why or why not?

Compare your lists of estimates with the lists made by other students across the room. How well do they compare? Why is there a difference?